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The Sky's The Limit

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A Presentation By:
Joseph M. Del Balzo
Executive Director for Systems Operations

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Joseph M. Del Balzo is currently responsible for all Federal Aviation Administration (FAA) systems operations. As Executive Director for System Operations, he oversees air traffic control, airway facilities, as well as safety regulations for all air aircraft, airlines and airmen in the U.S. system.

Mr. Del Balzo began his FAA career in 1958 as an electrical engineer. He holds engineering degrees from Manhattan College and Drexel University, as well as an Honorary Doctor of Science from Embry-Riddle Aeronautical University. From September 1975 until May 1976, he attended Princeton University, completing a fellowship in Public Policy and International Affairs.

He directed the FAA's Technical Center from 1979-81 and headed the FAA's Eastern Region in New York from 1981-88. He then assumed directorship of the FAA's Office of Systems Development. In September 1991, Mr. Del Balzo was appointed to his present position.

Mr. Del Balzo, an instrument-rated, multi-engine pilot, has made frequent public presentations at major international meetings in Europe, the Soviet Union, and the Far East. He has also been the chief FAA spokesman for new technology at ais and space exhibitions at Farnborough, England; Beijing, China; and Le Bourget, Paris.

Del Balzo was born in New York and now lives in Washington, D.C., with his wife an son, who attends college.

AIR TRAFFIC CONTROL: THE SKY'S THE LIMIT

BY

JOSEPH M. DEL BALZO

EXECUTIVE DIRECTOR FOR SYSTEM DEVELOPMENT

"Air Traffic Control....The Sky's the Limit"--is an obvious word play meant to conjure up images of infinite airspace with no limitations on its use and a boundless capacity to accommodate aircraft. In other words....the aviation system of the future. The sky's the limit could just as easily describe what we can anticipate in terms of safety and efficiency in tomorrow's system.

In the 21st century, today's constraints on the freedom of pilots to fly when and where they want will be lifted forever. No longer will aircraft be restricted from takeoff, because a landing spot is unavailable at an airport across the country.

Pilots will not be forced to fly along fixed tracks or from one imaginary point in the sky to another, instead of choosing a more fuel-efficient direct route. Unique military requirements will be handled within the system instead of carving out special-use airspace.

Pilots will no longer be denied an altitude where the winds are advantageous, simply because that altitude is occupied by another aircraft. Twin revolutions in satellite and microprocessing technologies will mean new air traffic control applications that translate into unconstrained airspace.

In contrast to the permanent interstate highways which crisscross our country, flight paths of the future will be flexible--constantly shifting in space, never fixed.....defined only by the flight dynamics of the aircraft. They will truly be "high" ways (in the literal sense of the word) consisting only of computer-generated algorithms--and air.

Air traffic control is not a subject most people spend time contemplating. You board a plane without giving a second thought to the "behind the scenes" efforts that get you to your destination. Except for an occasional glimpse of the air traffic control tower as you taxi down the runway, the system is invisible to the end user--the flying public. The fact that the public takes our air traffic control system--and the safety it affords--virtually for granted, suggests the supreme confidence placed in it.

I want to take you on an odyssey that spans the life cycle of the air traffic control system. From its conception on a sand dune in North Carolina to its fledgling steps in the 1920s and '30s, we'll move on to discover how it survived rites of passage at mid-century, finally maturing into today's healthy specimen....on the verge of spawning another generation of air traffic control technology. And we'll take a glimpse into the future to see the evolution of the system.

The first air traffic controller got his job as a result of a coin toss. To determine who would be the first to pilot the Wright Flyer at Kitty Hawk, North Carolina, Orville and Wilbur flipped a coin. Wilbur won but used up his turn in an unsuccessful attempt at first flight on December 14.

And so, despite his hopes of being the test pilot, Wilbur Wright had to be content in the role of an incipient air traffic controller, running along side his brother on the sand dunes back in 1903....shouting instructions and words of encouragement to Orville, as the plane lifted into the air.

The world's first powered flight was accomplished with rudimentary air traffic control services. "Winds aloft" measurements were taken with the help of a hand anemometer, which recorded prevailing winds of 24 to 27 miles per hour that day. And the Kill Devil Life Saving Station had been placed on alert, similar to the help today's controller might request when a hazardous landing is anticipated.

This was the first in a long string of aviation firsts. It ushered in an era when pilots ventured forth with few navigational instruments and no ground markings to guide them on their journey. Airports did not yet exist, only landing fields...wide open expanses of land with sufficient area to set down a flying machine. Not specifically dedicated to aviation purposes, these fields doubled as baseball fields, farmers' pastures, and even a cemetery...any relatively flat stretch of earth looked good to a pioneer aviator who may have lost his way or was running low on fuel.

The need for an air traffic control system was foreseen by an aeronautical publisher and aircraft designer, named Alfred Lawson, as early as 1916. Able to accurately foretell aviation's near-term future, he predicted non-stop trans-Atlantic flights and regular passenger service would occur before 1930.

He also envisioned that prior to the year 1970, heavy airplane traffic would require the establishment of traffic rules of the air. This prophecy, as you know, came true in a much shorter time frame.

The art of air traffic control was born at terminals. Initial efforts were limited to ground control and consisted of stationing a flagman at a prominent spot on the airport to signal when planes could turn or take off.

Later, tower controllers used prearranged light signals, which pilots would acknowledge by rocking their planes' wings during the day or flashing their landing lights at night. A steady green light, for instance, meant cleared for take-off, while a flashing one instructed the pilot to continue taxiing. Controllers could not communicate with the pilot beyond visual range.

Outside the terminal area, navigation was a problem. This was illustrated by the plight of the pilot chosen to fly the first leg of the air mail service's inaugural run from Washington to Philadelphia. He was a young Army lieutenant, just out of flying school. Equipped only with a poor sense of direction, he took off from Washington amidst much fanfare and well wishes from President Woodrow Wilson. The lieutenant promptly lost his way and ended up landing in Waldorf, Maryland, 25 miles south of here. The mail had to be put on a train.

The pressure for nocturnal flights grew out of a desire to improve the efficiency of air mail service. At first bonfires illuminated the way--soon replaced by more sophisticated revolving beacons, which signaled the proximity of an airfield to pilots miles away. As early as 1923, the Post Office established an experimental lighted airway, en route between Chicago and Cheyenne. The route was soon extended to New York and before the end of 1926, stretched between San Francisco and New York.

Later, beacons were replaced with electric lights.

Until 1930, radio communication between aircraft and the ground was virtually non-existent. Aircraft operated in good weather on a "see and be seen" basis. By 1932, airlines were equipping their aircraft with the capability to communicate by two-way radio telephone with airline ground stations. But prior to the inauguration of this service, radio signals had to be sent and received by Morse code.

In 1930, the Cleveland Municipal Airport was the first to establish a radio-equipped tower, the forerunner of today's air traffic control tower. Although twenty cities would erect similar facilities over the next five years, Cleveland tower took the lead in developing the first set of ATC procedures, pioneering methods that would soon be copied by other airports.

By 1935, air traffic, boosted by the introduction of passenger-carrying airliners like the Douglas DC-2 and a thriving airmail business, severely strained the capacity of our nation's rudimentary airspace system. The problem lay in the fact that no one controlled en route traffic.

With no airway control to regulate flow, aircraft came into terminal areas randomly, often arriving at the same time to compete for a portion of the congested airspace. A New Jersey aviation official reported that Newark Airport often had "as many as 15 planes circling, all of them flying blind, trying to keep at a different altitude, some of them low on gas."

After a rash of near mid-air collisions, airline dispatchers in Chicago began exchanging position reports and recording the information in logs. This practice was noted by a former American Airlines operations officer, who immediately grasped the significance of what the men were doing. Aircraft could be controlled if air traffic information, collected at a central point, were used to keep aircraft separated.

Obviously, this was a job for the Federal government--specifically the Bureau of Air Commerce, formed in 1926 to regulate air safety, establish and maintain airways, and formulate air traffic rules. Short on cash, the Bureau made a proposition to the airlines. If they would immediately establish en route control, the Bureau would take over the operation of these air route stations when funds became available. It was a deal.

Between December 1935 and June 1936, air route ATC units were established at Newark, Chicago and Cleveland. On July 1936, the Bureau kept its word and took over these facilities, including their personnel.

The first generation air route system was manually operated and relied heavily on the controllers' ability to visualize the movement of aircraft in three-dimensional space. Airline dispatchers were go-betweens, relaying information and instructions between pilots and controllers, since they could not communicate directly.

Controllers posted incoming flight information on a wall-sized blackboard, *which was constantly revised to reflect new reports of takeoffs, landings, plus in-flight progress. Information from the blackboard was transferred to a large table map that depicted the air routes converging on that particular terminal area.*

Controllers placed small brass markers, shaped like shrimp boats but representing flights, on the face of the map. A shrimp boat's pointed end showed the direction of flight and came with a clip to hold a strip of paper. This recorded the flight's identity, time of departure and altitude.

The responsibility for controlling terminal traffic remained with airport operators until World War II, when at the urging of the War Department, the Civil Aeronautics Administration took over most of the nation's air traffic control towers. By 1956, the CAA had jurisdiction over 26 en route centers and 182 airport control towers.

Still the civil air traffic control system of that period was "more technique than technology." Lacking the visual means for tracking planes, a controller had to calculate the estimated position of flights over his sector, record them on flight data strips, post them on boards and pass them on to a controller in the next sector.

Heavy dependence on voice communications created situations like one pilot's description of entering a terminal area in New York or Washington at that time: "It was like trying to talk over an old-fashioned party-line telephone with everybody on the line hollering "Fire" at once."

What was needed to resolve the postwar "crisis of the airways" was some form of positive air traffic control, putting controllers in constant, visual contact with the progress of aircraft. The answer was a wartime technology known as radar, which would transform air traffic control from an art to a science. Radar displays replaced the static arrangement of shrimp boats on a map table, trading it for a dynamic presentation of aircraft movements as they were occurring.

The first civilian radar was the airport surveillance radar or ASR-1, fielded in 1948. Rescued from a junkyard by the Smithsonian, it is now on display in that museum.

Primary radar would become the "eyes" of the ATC system, giving the controller a real-time fix on an aircraft's exact position and distance from the control station. It also reduced separation distances between aircraft, because controllers no longer had to increase intervals between planes to compensate for guesswork.

Unfortunately, disputes between the CAA and the Department of Defense over control and configuration of the air navigation system combined with the outbreak of the Korean Conflict to divert resources and attention from the purchase of radar and other ATC hardware. A meager 32 airports had surveillance radars by the end of 1955, and only 2 long-range en route radars were in place.

At the half-way mark of this century, the skies held a threat that had this country literally holding its breath. The post-war period saw an explosive growth in air traffic. In 1956 there were 1,480 air transports in service contrasted with 260 before the war began. A CAB study of the air traffic situation as it existed in 1956, caused one Congressional representative to remark that "near collisions in midair, of disastrous proportions, are being narrowly averted every day only by the emergency action of skilled pilots--or by providence."

The tragedy everyone dreaded eventually struck over the Grand Canyon in 1956. Two airliners collided, taking 128 lives. This accident, followed by several more mid-air crashes before the fifties were over, served as a wake-up call to galvanize the aviation community into action. It shook loose funding from Congress for the acquisition of 82 long-range surveillance radars for joint civil-military use.

Two mid-airs between military jets and commercial transports in 1958 also settled the long-standing jurisdictional dispute between the CAA and DOD. The CAA immediately gained control over all airspace designation and reservations.

The stage was set for making positive control a reality. Controllers would finally be able to segregate aircraft using instrument flight rules from those using visual flight rules--fast-moving traffic from slow-moving traffic. Controlling such a mix of traffic was becoming a real problem, as recognized by the FAA Deputy Administrator back in 1958, when National Airlines inaugurated domestic jet service: "Using a pilot's eyes is fine when you're doing 180, but when two planes are closing at a thousand miles an hour, human eyesight isn't that good."

For all its advances the second-generation ATC system was still too labor intensive. Seventy-five percent of the controller's time was being spent in voice communications or marking shrimp boats, now blips on radar screens instead of table maps. Information about the identity and altitude of flights continued to be kept on hand-written flight strips.

From its inception in 1958, the newly independent Federal Aviation Agency threw its talent and resources into developing a semi-automated ATC system capable of meeting the airspace system's growing need and performing ATC functions more rapidly and accurately than the controller could on his or her own. In the 60s and 70s, FAA began introducing equipment that transmitted flight information automatically and displayed identification, heading and altitude directly on the scope.

As radar had been the distinguishing technology of the second-generation ATC system, the computer became the driver of next-generation equipment. Without it, we would not have been able to handle aviation's growth nor establish a safety record that has become the envy of the international aviation community.

You may have read that some ATC equipment in use today borders on obsolescence. A rumor circulated recently that the curator of the

Smithsonian's Air and Space Museum called FAA, asking if the agency would donate one of our radar scopes from the 1960s for display. The story goes that we had to turn him down......the equipment was still in use.

It is true that controllers still rely on some equipment designed in the 50's, built in the '60s and delivered shortly before the '70s. There are secretarial workstations in the Centers which have more horsepower than many of the computers we use to control traffic. Should anyone wonder, however, if our safety record is just a fluke or whether we can continue to maintain safety given our not so state-of-the-art equipment, simply reflect on the thousand of sorties flown during Operation Desert Storm. The military system that kept those planes safe and separated is based on the same ATC technology used in civil aviation.

Modernization of our present ATC system is underway. The FAA's Capital Investment Plan, blueprint for this modernization, is being implemented and has already begun to pay dividends. This new Host Computer System, operational at all 20 en route centers since December 1987, is just one example. The Host offers 4 times the speed, 10 times the capacity and much greater reliability than the computer it replaced.

We are gradually introducing over $30 billion of new equipment (depending on how you crunch the numbers).....new radars, state-of-the-art controller screens and workstations....an advanced automation system with the largest real-time computer ever built, which will be the heart and soul of the future system.

And what does the new system promise in terms of weather data? It is not enough to tell the pilot that tomorrow it will snow in Illinois. He wants to know if it will snow tomorrow at O'Hare Airport, at what time, and how hard.

Improved weather information, both near terminals and aloft will be a major feature of the future traffic management system. Real-time weather observations will be transmitted from aircraft to the ground via datalink. These observations will be fed to sophisticated weather models to produce short-term and long-term weather products that will be communicated back to flight crews via ground-to-ground datalink. New Doppler radar systems customized for weather detection will be deployed at major airports throughout the U.S.

While the transition to this new system must be evolutionary, improvements to air traffic management will be revolutionary. The most difficult problem facing ATM system designers today is how to integrate new technologies into current operations.

Making this transition has been likened to changing a tire on a car travelling eighty miles per hour. Each incremental addition of new equipment has to work and work the first time, because the system can't be shut down.

To illustrate the radical difference between today's ATC system and that of *tomorrow, I want to take you on two flights of fantasy. In both, you will be the pilot, not a passenger. I want you to experience today's ATC system and that of tomorrow "hands-on."*

In the first scenario, it's 1992 and you are in command of a corporate jet, based at Midway Airport in Chicago. Before flying the company CEO to Washington, DC, you first obtain a pre-flight briefing by phoning a specialist at an FAA flight service station. The briefing contains all the pertinent surface, airborne and en route weather and aeronautical information currently available. Because of limited visibility, it will be necessary to operate your jet according to FAA-issued Instrument Flight Rules--procedures which pilots certified to fly in all-weather conditions must use.

You next file your flight plan with the FAA. This plan provides our agency with the information necessary to fit your flight into the national airspace system at a time when thousands of other aircraft are vying for equal time.

As you start the engines and leave the boarding area, you are in communication with "ground control" in the air traffic control tower. Your every move before takeoff will be directed by this controller.

Your aircraft taxis toward the active runway, queuing up behind another jet in line to depart. As you await your turn, you receive updates concerning runway wind conditions, until finally a local controller issues you a clearance onto the runway and permission to takeoff.

As you lift off, another controller issues the altitudes and headings to fly, as well as traffic advisories--all essential to maneuver your jet safely into the flow of traffic already in the system.

As you climb out of the Chicago terminal control area, defined as the volume of airspace around and above the airport, "departure" air traffic controllers take over. Located in the Terminal Radar Approach Control or TRACON at the airport, they guide your aircraft away from Midway to its destination.

Your plane passes a designated point in the sky, which marks the beginning of the defined air route you will fly. The aircraft has entered a large volume of airspace under the watch of controllers at the Chicago Air Route Traffic Control Center--one of 23 large facilities that control our en route airspace.

As you continue across the country, your jet is handed off from one controller to another as it passes through sector after sector. Ninety minutes after leaving Chicago--before entering Washington terminal airspace--you contact the arrival control facility located at National Airport.

Once again you receive traffic and weather advisories, as well as speed and altitude instructions--this time from the Washington TRACON--to ease your jet into the stream of arriving traffic. At this point, you speak with a local tower controller, who gives you final approach instructions, runway wind and surface conditions, and clears you to land.

Your wheels touch down, and ground control directs you away from the active runway, giving advisories along the way as to the intentions of other moving traffic. You taxi to a stop and shut down your engines.

Now fast forward to the year 2015. Older pilot, newer jet. Your preflight process consists of activating the on-board computer and logging onto the ATC system. This begins a dialogue between the two computers that will continue during the course of the flight--an exchange of information conducted via digital data channels.

You identify your aircraft and destination and within moments Air Traffic generates departure time and route alternatives. Once the route is established, the data is transferred directly into the aircraft's flight management system to lock in your anticipated trajectory.

There's no need for a weather briefing. The ATC computer has already factored all significant weather phenomena into its route-generation routine. A touch of a button provides a read-out of weather conditions along your route, automatically updated if significant changes occur. The aircraft will continually self-correct its course in flight to avoid adverse weather.

Airport surface maps reside in the data base of your aircraft's computer, enabling you to call up Midway on your cockpit screen. If your on-board system did not have a map of Midway in its data base, ATC would have downloaded one on request.

The ATC and on-board computers, communicating via datalink, integrate controller instructions and data regarding other traffic onto the surface map display. Your taxi instructions automatically appear on the cockpit screen. Because of the accuracy of the satellite and ground-based surveillance systems, you are confident of your exact position relative to every vehicle on the airport, even in the worst possible visibility.

Because the departure of all traffic has been choreographed by the ATC computer to within seconds, there is no need to wait in a queue. Your takeoff clearance appears on the cockpit display. As you lift off, your flight management computer immediately takes over navigation, with the aircraft's autopilot responding to the data entered by the ATC computer all the way to Washington.

Air traffic computers continually evaluate the current situation in the air, providing controllers the information necessary to issue instructions to en route aircraft. The computers have the ability to look fifteen to twenty minutes ahead of the aircraft and predict potential conflicts before they can occur. The perfection of airborne collision avoidance equipment serves as an additional safeguard to airborne conflict.

About 200 miles out of Washington, an ATC computer notifies you of the exact point your jet will begin its descent and the exact time of your arrival at National Airport.

Still on autopilot, your aircraft follows a predetermined descent path toward the turn to final approach. Once on the surface, the taxi map appears on the cockpit display, and you are home free.

How close are we to this 2015 scenario? Closer than you might think. The major challenge in designing tomorrow's system is not technology. The technology of the future is here today. The real test is our ability to totally rethink today's system to take advantage of the new capabilities these technologies offer.

The core components of future air traffic management--communications, navigation and surveillance--will be satellite-based. Satellites for datalink communications and surveillance are currently available. Their capacity will expand by a factor of 3 in the mid-nineties, a factor of 10 by the turn of the century and a factor of 20 by the year 2010.

At this moment our ATC system is still predominately voice-based. The other day I took a cab--I believe it was a 1983 Ford--to the airport. The cab driver communicated with his dispatcher at home base by datalink. I arrived at National, grabbed my suitcase and boarded the plan. In the cockpit of that $100 million aircraft, the pilot was picking up a carbon mike to speak to the controller. What an anachronism!!! For that kind of operation, he should have worn goggles and a silk scarf.

The FAA has begun developing a non-voice communications system called datalink to electronically transfer digital messages, such as weather updates and control information, to computer display screens located on the ground and in aircraft cockpits. Datalink is expected to reduce ATC voice communications by more than 50 percent, relieving overburdened radio frequency channels.

Near term, FAA is focusing on a new radar-based technology, called Mode S, to transmit these digital messages, but satellites are waiting in the wings to take over this function.

Chicago O'Hare and DFW Airport are among 29 airports already using datalink technology for transmitting predeparture information over VHF datalink channels and have eliminated over 60 percent of the voice traffic in this area.

Satellites can now be used to transmit aircraft position reports via digital datalink from the aircraft to an air traffic control facility. An aircraft's exact location is relayed automatically at pre-determined intervals without direct intervention from either the pilot or the controller. This concept called Automatic Dependent Surveillance or ADS is already in limited operational use in the oceanic environment.

Along the same lines, the FAA has implemented our Dynamic Ocean Track System or DOTS at Oakland, Anchorage, and New York Air Route Traffic Control Centers. This system provides automated management of the oceanic traffic flow utilizing existing hourly aircraft position reports. These reports, now obtained from high frequency communications, will eventually *be received from a global navigation satellite system.*

Cockpit technology has outstripped our capabilities on the ground. Newer transport jets, such as the Boeing 747-400, already have the so-called "glass cockpit," featuring a flight management system and VHF datalink communications. On-board computers provide a real-time capability for optimizing route and altitude profile, currently unmatched in our ATC center. Although the plane can generate four-dimensional flight profiles, the pilot must still verbally negotiate the user-preferred route with the controller.

Traffic avoidance and collision alert systems have also been installed in our large commercial aircraft fleet. This airborne technology gives the pilot audio and visual warnings if another aircraft is too close....in time for evasive action, if necessary. TCAS, as it is called, guarantees separation and affords extra security to aircraft operating under positive control, while giving some protection to those operating outside of it.

And how far are we from solving the problem of inclement weather? Later this year, the FAA will start testing a new concept called "synthetic vision," on a Gulfstream II business jet. This technology promises the potential to allow aircraft to land under weather conditions that would normally shut an airport down. The system uses millimeter-wave and infrared sensors to penetrate fog, creating an artificial image of the airport surface on a "heads-up" display, so that the pilot can land.

While the FAA is encouraged by this kind of progress in the air traffic control arena, we will never be content until we have a system that is free from fatalities, free from terrorism, free from delay, free from any adverse impact on the environment.

Let's take a glimpse at air traffic control in the far distant future. The collective intelligence of on-board computers, not human ground personnel, will be responsible for air traffic control. The aircraft's flight module will have the global satellite-based navigation equipment capable of negotiating the journey from takeoff to landing with no human intervention.

Thanks to satellites each aircraft will know its own position and velocity relative to the position and velocity of nearby aircraft. Computers will screen data from satellites for possible collision trajectories, introduce traffic management strategies and correct the plane's course--all without intercession from the pilot or ground control.

As we approach the time when this becomes reality, tactical role of both the pilot and the air traffic controller will gradually diminish.

The pilot will be less and less involved in flying the aircraft during heavy traffic conditions or on takeoff and landing. At these times, when the opportunity for error is the greatest, the human reaction time of 0.3 seconds will be no match for a sophisticated, computerized system with a response time that must be measured in microsecond time scales.

It's been said that the flight crew of the future will be a pilot and a dog. The dog's in the cockpit to bite the pilot if he tries to touch the controls. Don't believe it for a minute. The pilot will always be the system manager of an aircraft.

With the advent of automated decision-making in the ATC arena, the controller's role advances from that of a tactician to manager. Emerging computer technologies will form the basis for a replacement computer system as they mature....at first performing routine tasks requiring detailed computations and eventually offering controllers the number-crunching power to answer the "what if" strategic planning questions in real time.

Computer training will be the key. I'm not talking about training our people to utilize automation; I'm speaking of teaching computers how to think like air traffic controllers have thought over the decades.

In time, this kind of artificial intelligence will serve as an "associate" controller, keeping the airspace manager apprised of new data and potential strategies to deal with developing situations. The computer will be responsible for separating aircraft, and the human element can concentrate on things that computers are not good at, such as reacting decisively and appropriately in times of crisis...knowing what to do if the computer malfunctions or goes down.

How to handle the long-term evolution of the controller's role from tactician to manager is FAA's human resource challenge. Presently, we have over 22,000 air traffic controllers in our towers, centers and flight service stations--highly dedicated and competent individuals, who hold in their hands every day the lives of more than a million people.

At some point in the 21st century, they must stop being controllers and become managers. An individual who is psychologically suited to one role may not adjust well to the transformation of his duties. As a friend of mine pointed out, Rambo could never be a manager. We must strike just the right balance between controller/computer responsibility.

The air traffic control system of the future will use all kinds of advanced technology to <u>support</u> our aviation professionals--on the ground: controllers...engineers....technicians.....safetyinspectors--and in the air: pilots.....flight attendants. Advanced technology will never <u>replace</u> them.

What does this all mean to you the passenger? The future ATC system will have two things in common with its predecessor:

- *Today the U.S. aviation system unquestionably is the safest, most modern air transportation system in the world. It will be the same in the 21st century. Air travel will be as close to perfection as is humanly possible. Safety will always be the number one priority.*

- *The system will remain transparent to the ultimate user--the passenger.*

That's not to say that the passenger won't derive tangible benefits from the emerging technologies I've described. Ticket price may be impacted by the airlines' ability to save millions in jet fuel costs, solely because planes will fly the most fuel-efficient routes. And that dreaded "D" word ....DELAY ....will never again be mentioned in the same sentence with "air travel," except when someone recalls the hassles of flying in the twentieth century. ###

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